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ABSTRACT

More than two decades ago, hybrids of sweet-stalked (SS) corn were proposed as high-value feed silage. Because of their high sugar contents, they now assume new importance as crops for energy or as multi-purpose crops for both feed and energy. Existing unpublished data from a 2-year study reveal that stalk yields of SS hybrids and a check hybrid were similar at harvest; but during silage stage (September), stalk sugar contents (30 and 34%) of the SS hybrids were 1.2 to 1.6 times those found for the check hybrids. Data for materials obtained after a heavy frost showed that, while sugar contents declined for all hybrids, the SS hybrids had sugar contents of 2 to 3-½ times those of the check hybrids (6-7%). The SS hybrids merit further study to evaluate more fully their potential not only to produce grain but also to produce fermentable sugar and cellulose.

INTRODUCTION

The presence of sugar in cornstalks has long been known. Stalks of corn provided sugar to the Aztecs even before the Spanish Conquest of Mexico (Singleton, 1948). Since corn can produce and store large quantities of sugar in the stalk, silage of high value may be produced from hybrids of high-sugar inbreds (Jugenheimer, 1976; Singleton, 1948). Blanco *et al.* (1957), in Spain, and Jugenheimer and Williams (1959), working with selected Spanish hybrids in Illinois, experimented extensively to develop corn for dual purposes, grain and stover (cured stalks used as fodder); at maturity, the stalks still contain high quantities of sugar. More than twenty years ago, we initiated a study to evaluate sweet-stalked (SS) corn as a possible multi-purpose crop for the United States. The grain and stover yields were determined, and the stalk was examined as a possible sucrose source or a high-energy silage or fodder. With current interest in biomass resources and multi-purpose crops (Buchanan and Otey, 1979), those data assume greater status. Consequently, we reevaluated these previously unreported data in terms of current interests.

*The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

MATERIALS AND METHODS

During the first year, seven Spanish hybrids of SS corn and one hybrid common to the Corn Belt were grown at the University of Illinois. Replicated plantings were harvested at three intervals; before frost (silage stage), after a light frost, and after a heavy frost. Of samples containing 40 stalks, five or six stalks were randomly selected, sectioned, and frozen. Leaves from the last two harvests and ears from the first harvest were discarded. All samples were freeze-dried and then ground in a Wiley mill to pass a 1-mm screen. Samples were analyzed for reducing and total sugar contents and nitrogen.

In the second year, four SS hybrids and one Corn Belt hybrid were grown as before. These hybrids were harvested in triplicate at two dates; before frost and after a heavy frost. From each sample, six to eight stalks were separated into ear, shuck and shank, leaf, and culm components. The culms were sectioned and frozen as were the leaves, shucks, and shanks. After being freeze-dried and ground in a Wiley mill to pass a 1-mm screen, all samples were analyzed for total sugar content and nitrogen.

Sugars were extracted and hydrolyzed by a modification of the official methods for reducing sugar and sucrose (Association of Official Agricultural Chemists, 1955). The Micro Method for reducing sugars was used to analyze for sugar content of all samples. Nitrogen was determined by the Kjeldahl method and calculated as crude protein. Yields of forage and grain were calculated on the basis of assuming 15,000 plants per acre and one ear per plant.

RESULTS AND DISCUSSION

Sugar contents in culms of seven SS corn hybrids were higher than those in the culms of a Corn Belt hybrid check (Table 1). Reducing and total soluble sugars of the SS hybrids exceeded those of the check at both the silage and post-frost stages. Reducing sugar, representing about 50% of the total sugar, decreased somewhat less between harvest intervals than did sucrose. Such a high percentage of reducing sugar would seem to render impractical the use of the stalks as a source of crystalline disaccharide. However, this would be of no concern if the sugar remains as an added energy source in a silage or fodder. Lack of crystallinity would likewise be inconsequential in serving as a fermentation substrate. The total sugar contents in the stalks of the SS hybrids exceeded those of the control 1-½ times at the silage stage and increased that difference to 3-½ times after a heavy frost.

In the second year of the study, total soluble sugars present in all components of the stalks were determined at silage and post-frost harvest stages (Table 2). With the possible exception of the leaf fraction from the post-frost harvest, the four SS hybrids contained more sugar in all components than did the Corn Belt hybrid at the respective harvest stages.

Nathan (1978) reported on the evaluation of sugar crop grasses, e.g., sugarcane and sweet sorghum, as raw materials for producing fuel and chemical feedstocks. Sugarcane was considered most promising, with sweet sorghum becoming more promising in the future after more developmental work.

An examination of a report by Lipinsky *et al.* (1979) reveals that maximum total sugars in stalks, at experimental sites in 1978, from sugarcane (3 locations) and sweet sorghum (5 locations) were 34-52% and 29-34%, respectively. In the two-year study of SS corn, total sugars in the culms at silage stage were 28-40%. Although the SS corn did not contain as much total sugar as reported for some sugarcane, its range of values overlapped that of sweet sorghum and part of the range of values for sugarcane.

To select varieties for multiple use or for biomass to produce alcohol, using stalks as well as grain, the chemist, microbiologist, and plant scientist would be interested in total yields per acre. The limited data acquired in this study indicate that forage yields of SS and Corn Belt hybrids are similar (Table 3). However, in the important criterion of grain production, these limited data indicate that the control hybrid is more productive. These data are consistent with yield data reported by

Table 1. Sugar in Cornstalk Culms* (Oven Dry)

Identification	Silage stage sugar,		Post-frost harvest sugar,	
	Reducing, %	Total, %	Reducing, %	Total, %
Sweet-stalked, P.I. no.				
240056	19.1	40.4	9.4	17.6
240057	16.2	33.9	6.8	14.8
240058	15.4	28.0	10.7	20.1
240066	14.8	35.0	13.2	26.2
240067	17.2	35.8	14.0	26.6
240070	19.0	34.1	15.1	26.4
240071	16.6	32.8	11.9	19.6
Check, III. no.				
1570	12.0	21.2	4.5	6.0

* First year experiment.

Table 2. Sugar in Corn Plants* (Oven Dry)

Identification	Sugar, total %					
	Silage stage			Post-frost harvest		
	Leaf	Shuck and shank	Culm	Leaf	Shuck and shank	Culm
Sweet-stalked, P.I. no.						
240057	5.5	23.1	28.9	0.8	3.3	15.9
240058	5.7	25.3	28.2	3.0	3.2	13.7
240066	4.7	24.4	32.0	2.3	2.7	10.7
240070	6.2	21.5	30.8	0.6	3.0	10.8
Check, III. no.						
1570	4.0	20.5	25.8	1.8	1.9	7.0

* Second year experiment.

Jugenheimer and Williams (1959). By contrast, Blanco *et al.* (1957) found that their group of experimental SS hybrids yielded more grain than did a group of standard American hybrids.

Since corn silage is deficient in protein, an evaluation of new varieties of corn for silage should emphasize their protein content. The corn plants of SS and control hybrids analyzed in this study were similar in protein content (Table 4). Based on protein content, the leaf appears to be the most nutritive part of the plant, but it stores little of the sugar. Consequently, it should be technically feasible to divert the leaf for feed and leave most of the carbohydrates for fermentation.

Lipinsky (1978) suggested a change of the usage of the corn biomass system in the United States. His proposal would permit production of 10-18 billion liters of ethanol from the grain while maintaining the same quantity of food in the form of beef, poultry, and pork. After ethanol production, the protein rich stillage from some of the grain would be fed to ruminants. An amount of corn stover equivalent to grain used for ethanol would be harvested and fed with the stillage to the cattle. The quantity of grain fed to nonruminant animals (poultry and hogs) and grain converted into starch and other byproducts would not change. That concept should allow removal of most soluble sugars from SS hybrids without adverse effect on feed value when compared to traditional hybrids.

Table 3. Corn Crop Production of Experimental Hybrids

Hybrids	Yields *		
	Forage		Grain
	Silage stage lbs/a (d.b.)	Post-frost harvest lbs/a (d.b.)	bu/a
Sweet-stalked	5850	3380	95
Check, Ill. 1570	5380	3160	114

*Calculated on basis of assuming 15,000 plants per acre and one ear of corn per plant.

Table 4. Protein in Corn Plants (Oven Dry)

Identification	Protein, %			
	Silage Stage		Post-frost Harvest	
	leaf	Culm	Culm	Grain
Sweet-stalked	14.2	3.2	3.5	10.8
Check, Ill. 1570	13.0	3.5	3.5	9.4

The residue from the most important crop of American agriculture, corn, can provide domestically renewable products for liquid fuel. With high content of polysaccharides, cornstalks are of special interest for conversion to sugars for alcohol or chemical feedstock production. In selection of corn hybrids, high sugar contents demonstrated by the SS hybrids would be beneficial as a feedstock for alcohol or feed for animals. More sugar in the stalks makes the plants even more desirable for alcohol fuel production. Even after a heavy frost, the 13-22% sugar in the SS hybrids compared to the 6-7% in the control makes these stalks more valuable as feedstock for ethanol production.

Further work with SS corn should enhance yields of grain as well as forage with favorable carbohydrate contents. The wealth of information about corn and the quantity of fermentable sugars produced and maintained by SS corn could be used to develop a multi-purpose crop system. Both basic and applied research studies need to be initiated to further improve the desirable characteristics of SS corn and to develop its agronomic, harvesting, handling, and storage technology.

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